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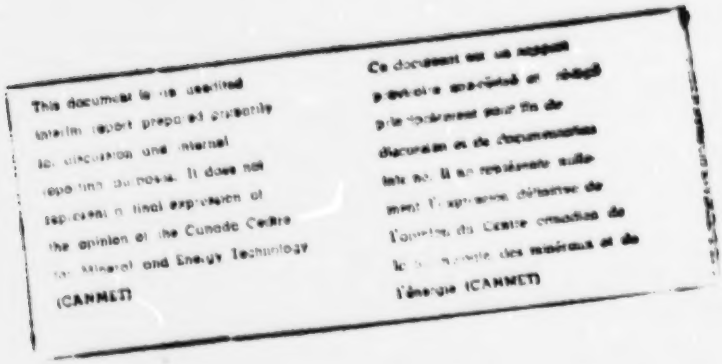
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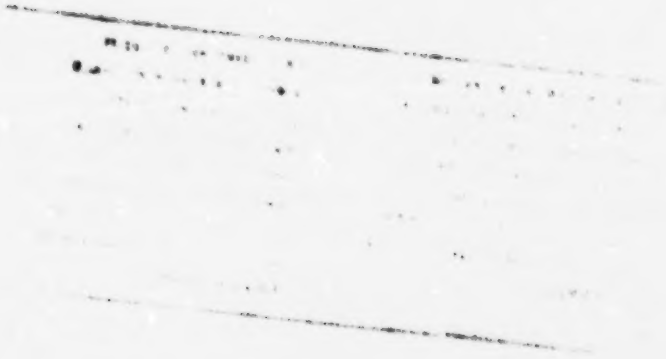

REVIEW OF DUST CONTROL AND ENGINEERING PARAMETERS IN LOADING

G. Knight* and J. Pathak**

ABSTRACT

The main sources of airborne dust in loading are reviewed under the following headings: generation of fines in the previous operations; suppression of fines already present by wetting; the control of breakage in the loading operation; the control of dust dispersion using local airflow; reduction of the operator's dust exposure by local airflow control.

Recommendations for further studies are outlined as follows: measurement of fines; control of fines in blasting; wetting of standing ore in the stope; wetting of sulphide ores; and the study of dust generation and engineering parameters in loading.

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KEYWORDS: Hard rock mining, Rock loading parameters, Dust control

REVUE DES PARAMETRES DE DEPOUSSIERAGE ET DES FACTEURS TECHNIQUES DANS LE CHARGEMENT

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RÉSUMÉ

Les principales sources de poussière en suspension dans l'air au cours du chargement sont passées en revue sous les rubriques suivantes: prduction de fines dans les opérations antérieures; suppression des fines déjà présentes par mouillage; contrôle des bris dans le chargement; contrôle de la dispersion de la poussière au moyen de courants d'air localisés; réduction de l'exposition de l'opérateur à la poussière en réglant la circulation d'air localisée.

Suivent des recommandations sur de prochaines études: mesure des fines; contrôle des fines pendant le tir; mouillage du minerai abattu dans les chantiers; mouillage des minerais sulfurés; et étude des paramètres de production de la poussière et des facteurs techniques dans le chargement.

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MOT CLES: exploitation des mines de roche dure, paramètres de chargement de la roche, dépoussiérage

INTRODUCTION

It has been shown that loading rock is the main dust source for potential airborne dust exposure to hard-rock miners in the active ore extraction area(1). Table 1 shows a summary of dust production in an entire mine and table 2 shows the dust production at the slushing and loading operations as measured in a number of mines. The average value determined in each set of tests is given. This data is taken from reference 1.

Table 1 – Estimates of total dust produced in one shift at one mine

Operation	Tonnes	Respirable dust production gm/shift				Mineral dust as % of	
		Total	Combustible	Mineral	Quartz	Entire mine	Mining area
Between shift main blast		5600	2800	2600	1300	34	
MINING AREA							
Secondary blasting	100	20	80	80	40	1	15
Slushing	2400	350	20	330	165	4	63
Mucking	400	40	30	10	5	0.1	2
Car loading	2700	115	60	56	27	0.7	10
Drilling	2700	22	20	3	1	0.1	0.6
Scaling etc.	—	10	—	10	5	0.1	2
TOTAL		637	150	487	243	6	100
OUTBYE							
Rail transport	2700	65	60	5	2	0.1	
Dumping into orepasses	2700	60	10	50	25	7	
Orepasses	2700	2700	60	2600	1300	34	
U/G crusher	2700	1800	—	1800	900	23	
Skip loading	2700	160	40	100	50	1.3	
TOTAL		6800	170	4600	2300	60	
TOTAL all underground		11000	3100	7700	3850	100	

While blasting produces more dust the airborne dust portion is usually carried away from the mining zone by the ventilation current prior to the miners returning after the blast. Thus it is not a source of dust exposure to miners.

The dispersion of dust into the air can be considered in two parts: firstly, that of the fine dust already present in the broken rock and, secondly, that of dust produced in fresh breakage while disturbing the rock pile. The control of dust during loading can be considered under the following headings:

1. Control of the generation of fines in previous treatment stages, usually drilling, explosive loading and blasting.

Table 2 — Dust production in loading rock

Operation	Number of tests	Mean respirable dust production (mg/tonne) Total	Combustible	Mineral	Quartz
Mucker in heading	3	90	80	24	11
Slusher in raise	3	18	2	35	18
Slusher in stopes					
Site 1	4	87	7	80	40
2	4	210	120	90	45
LHD in headings					
Site 1	1	143	43	100	23
2	3	750	450	180	20
3	9	600	360	240	103
LHD in drawpoints					
Site 1	4	270	200	110	30
2	5	325	270	55	25
Range of site means		18-750	2-450	24-240	11-103
Grand Mean				140	

2. Suppression of dust dispersion of fines already present by wetting.

3. The control of fresh breakage in the loading operation.

4. The control of dust dispersion by control of local airflows.

5. Dilution of dust by ventilation.

6. The control of dust exposure to the operator by control of local airflow.

7. The control of dust exposure to other miners by control of ventilation routing.

8. In addition to the above, ancillary operations such as transfers and dumping should be considered.

This report discusses each of the above items in the following chapters. There is some overlap between these topics which will be discussed under the most suitable heading.

CONTROL OF FINES GENERATION IN PREVIOUS STAGES

The term, 'fines', is, in this report, understood to define broken rock in the size range which has the potential of being dispersed into the air and becoming a hazard to the miners when inhaled. This corresponds to sizes up to about one-twentieth of a millimetre. Generally, however, in mining the term is understood to include particles up to about one millimetre in size.

The loading operation is usually preceded by a number of mining operations as follows:

1. Drilling
2. Loading of explosive
3. Blasting
4. Falling

The influences of these on the fines present at loading are considered.

Drilling generally produces a substantial amount of fines in relation to the amount of rock actually broken. It is clear that an efficient drilling process will produce less fines and more coarser rock fragments(2). It is also probable that effective dust suppression, as in wet drilling, will leave more fines in the broken ore. However, only a small portion of the total rock is broken in drilling and it is probable that it contributes only a small fraction of the total fines present at loading.

Explosive loading is not expected to be a significant source of fines at loading.

The primary breakage occurring during blasting is expected to be the main source of fines present at loading. Some of the fines produced will be dispersed into air at the blast and swept away thus decreasing the fines at loading. It has been shown that the amount of fines produced is proportional to the amount of breakage occurring(1,2). Table 3 shows the minimum amount of fines expected for breakage to various maximum sizes.

TABLE 3— The Generation of Fine Dust when Breaking Massive Rock

maximum rock size metre	fines present gm resp dust/t
1	19
0.75	23
0.5	31
0.25	50
0.1	105
0.05	290
0.01	600

It can be seen that the amount of fines produced increases rapidly as the maximum rock size is reduced. The amount given here is the minimum quantity for breakage to a given size, it can be increased by uneven breakage throughout the rock mass induced by poor blasting. Clearly blasting technique is very important in controlling fines

at loading(3). Presumably fines generation will be minimized by minimizing energy input into breakage. Most studies on blasting have been more concerned with minimizing oversized fragments than with fines. Possibly a major factor in the lack of attention paid to fines generation is the lack of a suitable tool to measure it in the mining situation.

The fourth factor considered is secondary crushing occuring after the fragmentation induced by the blast itself. Two mechanisms are clearly possible: firstly, breakage as a result of kinetic energy applied to the rock fragments in the blast leading to collisions and breakage and, secondly, free fall of the rock fragments providing energy for further breakage. Excessive application of kinetic energy to the rock in blasting is a symptom of overuse of explosive or poor placement and should be avoided. Free fall following the blast necessarily occurs in some mining systems and should be minimized by limiting the expansion space available.

The major factor in further studies on blasting with respect to fines generation is development of suitable measuring techniques. A photographic technique with automatic processing of the size distribution has been tested(4). This is only suitable for the description of the large sizes and seems very unlikely to be extended down to the fine potentially-airborne sizes that are the major interest. It would seem possible to develop a washing, filtration and vacuum cleaner technique to collect the fines for later examination.

DUST SUPPRESSION WITH WATER

The use of water, or other liquids, for dust suppression in hard rock mines is almost universal. It prevents dust dispersion into the air by binding the fine particles to the coarser fragments by Van der Vaals forces. It can reduce the dispersion of fine dust already present almost entirely. In normal mine usage the technique reduces dispersion of dust already present by 30 to 90%. It is not nearly so effective on dust from fresh breakage, such as that considered in the next section.

The major factor in dust suppression with water is obtaining the required thin layer spread over every surface of the rock fragments. Silicate rocks, as distinct from sulphide, are mostly readily wetted by water alone. However, wetting can take a long time and this has to be fitted into the mining cycle. Periods of a few hours have been found to be required in some tests as shown in Table 4 abstracted from reference 1.

Table 4— Effect of wetting time on loading

Wetting operation	Number of tests	Respirable dust production (mg/tonne) Mineral	Quartz
Dry test no water	1	600	300
— 1.5 hrs wetting	1	110	55
Normal mine practise			
First 5 buckets	2	185	92
Most of muckpile	9	150	75
Extra wetting	4	62	31

Extra wetting consisted of 2 hours hose application with frequent moving to spread over the entire top surface of the muckpile

For sulphide rocks wetting is more difficult and wetting agents may be required. These have been shown to interfere with the subsequent flotation procedures frequently used in beneficiation(6). However methods of overcoming the interference were also found(7).

Spreading would be assisted by adding water during blasting. The problem is to add sufficient water without increasing other costs. Water stemming has been used, while the main objective was control of ignition in coal mines, it presumably is also effectively spread over the rock surfaces. The cost of drilling sufficient volume to contain the required quantity of water is probably prohibitive. The effectiveness of supplying atomised water to the face during the blast has not, to the author's knowledge, been tried; it's effectiveness is doubtful as it's penetration into the rockpile would be against the flow of gases from the explosive. The use of water stemming does have other effects on blasting such as increased coupling to the rock(3), and thus would probably affect dust formation. Any experiments would have to consider both fines generation in blasting and dust suppression in the subsequent loading operation. The quantity of water required for dust suppression depends on the amount of fines present and is of the order of 10 litres per tonne. This figure could be used in a preliminary assessment of the amount that could be added in blasting experiments.

In some mining methods, such as drawpoints, the ore is only exposed for a very short time in loading and obtaining full wetting is difficult(1).A very carefully controlled wetting of the ore standing in the stope might be feasible and should be investigated. Uncontrolled wetting could lead to the hazard of outrush of water and fines.

In sulphide ores wetting with water can be difficult. There is a need for definitive studies in sulphide ore mines to define the effectiveness of wetting and to investigate the usefulness of surface active agents in the practical situation.

FRESH BREAKAGE DURING LOADING

Fresh breakage during loading occurs when rocks are crushed by applying pressure with the loader. The crushing can occur between the rock and the tool, between rock and rock or between the rock and the solid rock bounding the excavation. One expects the fresh breakage to be related to the energy applied by the loader to the rock. However there have been no definitive studies on the subject of forces applied in loading loose rock. Most of the published documents are empirical in nature discussing the effects of bucket shape, teeth, oscillating action and operator finesse on ease and time of loading as well as on component wear(8-10). There have been some studies on the efficiency and duty cycles of a diesel powered scooptram. But no measurements were made of the power actually applied to the rock and thus not of loading efficiency(11). One report of instrumented tests on an excavator has been found(12). The object in these tests was to check component loads and it is not clear from the report whether the forces applied to the rock were determined.

It is clear that knowledge of the forces involved in entering a rock pile could be of value in loader design and control algorithms. In particular in designing the motions required to simulate a skilled operator's finesse in oscillating the bucket tip in entry. The vibratory motion has been shown mechanically feasible and useful on bucket loaders(13). Improved understanding of the loading process shows promise of improvements in loading and dust control.This is particularly important in remote and automatic loading where operator finesse is not available. The field of remote and automatic loading is where there is a major development thrust in the mining industry at present. A proposal on this topic has been prepared(14).

DUST DISPERSION CONTROL USING LOCAL AIRFLOWS

The amount of dust dispersed at a loading or rock handling operation increases with increasing air velocities through the interstices between the rocks. Some airflow is necessarily induced by moving the rocks. The objective is to avoid other sources of air movement by enclosure and directing the main ventilation airflow away from the disturbed rock as much as possible.

DILUTION OF DUST BY GENERAL VENTILATION

The general ventilation can dilute the dispersed dust to an acceptable level. This occurs after full mixing which may only be fully effective after the air stream has left the working area. Usually some 500 to 5 000 cubic metres of air are required to dilute each gram of respirable sized mineral dust to an acceptable level depending on the fraction of quartz present. Table 1 shows that this quantity can get very large for each ton of ore and that dust control is important.

A discussion of dilution ventilation in comparison with local control was given (15).

LOCAL AIRFLOW CONTROL OF OPERATORS EXPOSURE

Local airflow control of the operators dust exposure can be considered either as feeding fresh air to his breathing zone or as drawing the dusty air away such that it does not reach it. Forced air ventilation supplies fresh air to the working place. Control then implies ensuring that the stream of fresh air reaches the operators breathing zone without being contaminated by the dust being dispersed in the operation. Also the high velocity air leaving a forced ventilation duct is uncomfortable and has to be slowed down before reaching the operator. One approach has been to use diffusers directing the clean air towards the operators normal working position(16).

The application of this principle to operations with a loading machine, such as a scooptram, seem likely to be successful as the operator works within a defined plane, parallel to the floor, and a ventilation system could be set up to feed fresh air to this plane through a series of slits or jets from the forced air duct.

Exhaust ventilation with or without a filter has been used to reduce dust concentrations to the operator, such as push-pull and air extraction systems(16). The use of a filter has the advantage that dust exposure to workers downstream is also reduced. In drawpoints the dust is dispersed into the air at a distance in advance of the operator and exhaust ventilation dust control has considerable potential as long as adequate robustness in the rough working conditions can be obtained. When using a loading machine on a rock pile there is the possibility of machine mounted exhaust hoods and filters as long as a robust set up can be made.

CONTROL OF OTHER MINERS DUST BY VENTILATION ROUTING

Blasting and loading are usually the main dust sources in the extraction area of the mine and it is desirable to minimize the transport of dust from these operations to other workers in the mine. To achieve this by ventilation control requires attention to detail in the layout of the mining area and ventilation. Under these circumstances the dust and air can usually be considered to be well mixed and the dust level present is that given by "dilution ventilation".

An example of a problem found in a mine is shown in figure 1. Also shown is an alternative layout that would at greater initial cost have substantially reduced the dust exposure to all those working on this level(17). In this operation one major dust source was the multi-level ore pass. Such ore-passes require interconnection and air extraction to prevent leakage of the very dusty air produced in them(18).

ANCILLARY OPERATIONS

Ancillary operations, such as dumping into trucks and transfer points produce dust and affect the operators exposure. Thus they need to be considered in the dust control program. One example in mine planning was comparing a diesel powered load-haul-dump against an electric scooptram loading a diesel-powered truck; it was concluded that the first combination gave a lower expected total dust dispersion and was thus preferable.

In dumping a load from a scooptram or other loader it is desirable to minimize the fall of rock so as to minimize further breakage and dust emission. It is suggested that bucket controls should be modified to maintain a constant unloading height as shown in figure 2 for a scooptram at a grizzly.

Some dump points after the loading operation give rise to high dust emissions and their siting needs to be considered in relation to other operations to minimize dust exposure to all workers. An example is shown in figure 1.

RECOMMENDATIONS FOR FURTHER STUDIES

This section outlines areas in which further studies could be carried out. Each recommendation is given in full detail in a separate proposal.

1. Measurement of fines. An adequate method does not seem to be available and the first objective is to test methods in the mine(19).
2. Control of fines production in blasting. This study should be combined with a study of the size distribution of all the breakage products in blasting, and the consideration of handling requirements. This study cannot proceed until the previous study has determined a suitable experimental method.
3. Wetting of ore standing in a stope above a drawpoint. There is very little time available for adequate wetting of ore while it is being loaded from a drawpoint and methods of improved wetting could reduce dust emissions substantially(20).
4. Wetting of sulphide ores. Sulphide ores are difficult to wet and there seems to be scope for substantial improvement in wetting techniques. The first stage in the study would include studies on wetting times and dust suppression using water alone and water with surface active agent(s)(21). Precautions have to be taken that there is not excessive interference with subsequent flotation processes if they are used(6,7).
5. Study of engineering parameters in loading. Using an instrumented machine it is proposed to measure the forces required for a point or a blade to enter a pile of rocks in a simulation of the loading process(14).The study should include the influence of oscillation on the entry force into the rock pile and the influence on fresh breakage and dust generation.
6. Study of local airflow control in loading: fresh air systems. This is the examination of the outlet from forced air ventilation systems including diffusers and directional control towards the operator.
7. Study of local airflow control in loading: exhaust systems. This is the examination of possible applications of dust extraction systems to loading including loader mounted and fixed installations at drawpoints.

REFERENCES

1. **Knight G.** Generation and Control of Mine Airborne Dust *CANMET Report 80-27E* Energy, Mines and Resources, Ottawa (1980) *also abbreviated under same author and title in Pierre Mousset-Jones(ed) Proc. of the 2nd U.S. Mine Ventilation Symposium A.A.Balkema Boston (1986)*

2. **Hamilton R.J. and G. Knight** Some Studies of Dust Size Distribution and the Relationship between Dust Formation and Coal Strength *in W.H. Walton(ed) Mechanical Properties of Non-Metallic Brittle Materials* Butterworths Scientific Publications London (1959)

3. **Hagan T.N.** The Control of Fines through Improved Blast Design *Proc. Aust. Inst. Mech. and Metal.* No 271 9-20 Sept (1979)

4. **Maerz N.H., J.A. Franklin, L. Rothenburg and D.L. Coursen** Measurement of Rock Fragmentation by Digital Photoanalysis *in G. Herget and S. Vongpaisal(eds) International Congress on Rock Mechanics* Vol. 1 687-692 A.A. Balkema Boston (1987)

5. **Hamilton R.J. and G. Knight** Laboratory Studies of the Suppression of Dust from Broken Coal and Shale *Int. J. Rock Mech. Mining Sci.* 1 105-115 (1963)

6. **Cristovici M.A. and P. Lachapelle** Investigation to Select Suitable Wetting Agents as Sulphide Ore Dust Suppressants And to Study Their Influence on the Flotation Process *Division Report MRP/MSL 83-66(IR)* CANMET; Energy, Mines and Resources, Ottawa (1983)

7. **Cristovici M.A. and T. Gilmour** Investigation to Eliminate the Detrimental Effect of Dust-Suppressing-Wetting Agents on Flotation Results (Opemiska Copper Ore) *Division Report MRP/MSL 86-65(IR)* CANMET; Energy, Mines and Resources, Ottawa (1986)

8. **ANON** Loader Bucket Efficiency Boosted by Customizing *Pit and Quarry* 68 no.6 121-122 (1975)

9. **Atkinson T.** The Prediction and Reduction of Abrasive Wear in Mine Excavating Machinery *in Int. Conf. on Tribology in Mineral Extraction War on Wear– I. Mech E. Conference Publications 1984–11* Mechanical Engineering Publications, London (1984)

10. **Adler L. and M. Lotfi** Operator Response to Work Intensity of Front-End Loaders *in D.H. Graves(ed) 1983 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation UKY BU133* University of Kentucky Dec. (1983)

11. **Dainty D.** *Private Communication* CANMET Diesel Laboratory; Energy, Mines and Resources Ottawa (1987)

12. **Anon** Massive Hydraulic Shovel Exceeds Expectations *World Mining Equip.* 11 18-21 June (1987)

13. **Anon** Vibratory Bucket has Mine Potential *World Mining Equipment* 184-185 june (1987)

14. **Knight G. and J. Pathak** Proposal for Dust Generation and Engineering Parameter Study in Rock Loading *Division Report M&ET/MRL 87- (IR)* CANMET: Energy, Mines and Resources, Ottawa (1987)

15. **Goldfield J.** Contaminant Concentration Reduction: General Ventilation Versus Local Exhaust Ventilation *Am. Ind. Hyg. Assoc. J.* 41 812-818 (1980)

16. **Anon** Dust Control in Coal mining *MRDE Handbook No. 15* Mining Research and Development Establishment National Coal Board Burton-on- Trent (1978)

17. **Knight G.** Dust Control for Scooptram Operations *in D.R. Stewart(ed) Design and Operation of Caving and Sublevel Stoping Mines* 841-843 Am. Inst. of Mining, Metal., and Petrol. Eng., New York (1981)

18. **Mining Association of Canada** Design Guidelines for Dust Control at Mine Shafts and Surface Operations *Mining Assoc. of Canada Toronto* June (1973)

19. **Knight G.** Proposal for Development of Method for Measuring Fines Produced in Blasting *Report in Preparation*

20. **Knight G.** Proposal for Wetting Ore Standing in Stopes *Report in Preparation*

21. **Knight G.** Proposal for Tests of Wetting Agents for Dust Suppression on Sulphide Ores *Report in Preparation*

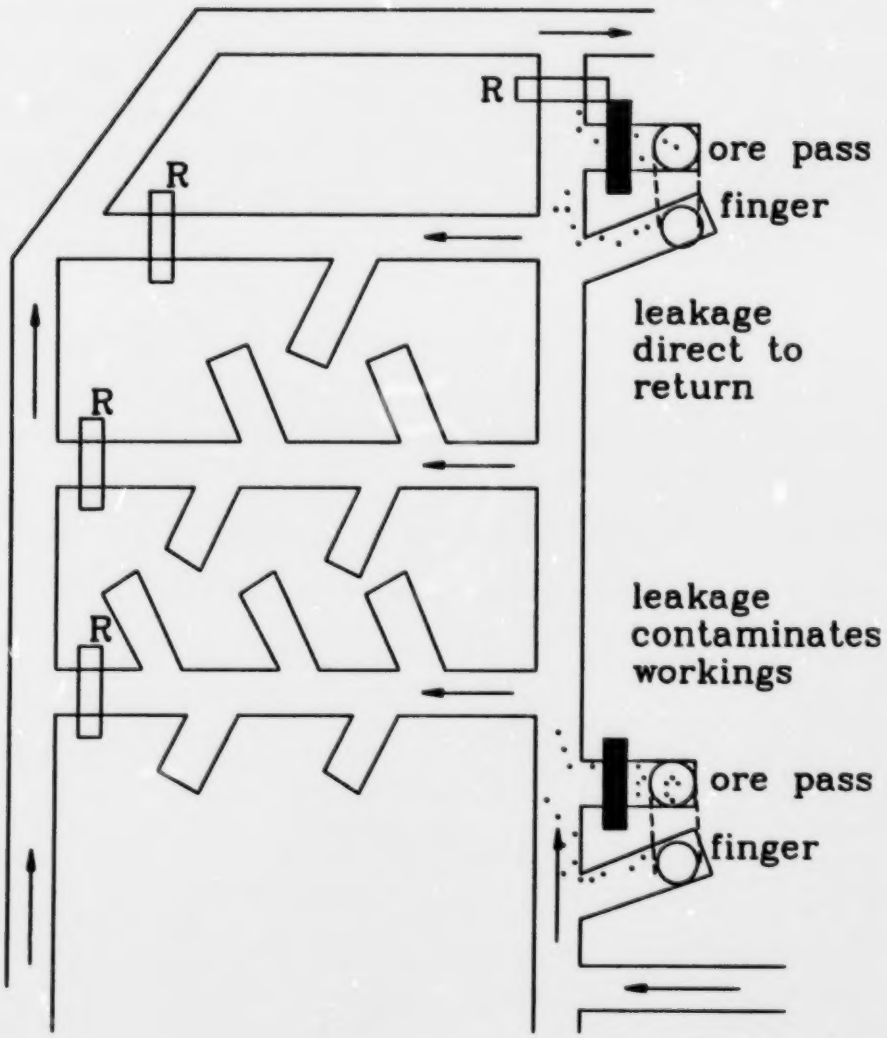

Fig. 1— Effect of dump point siting on dust leakage into working area

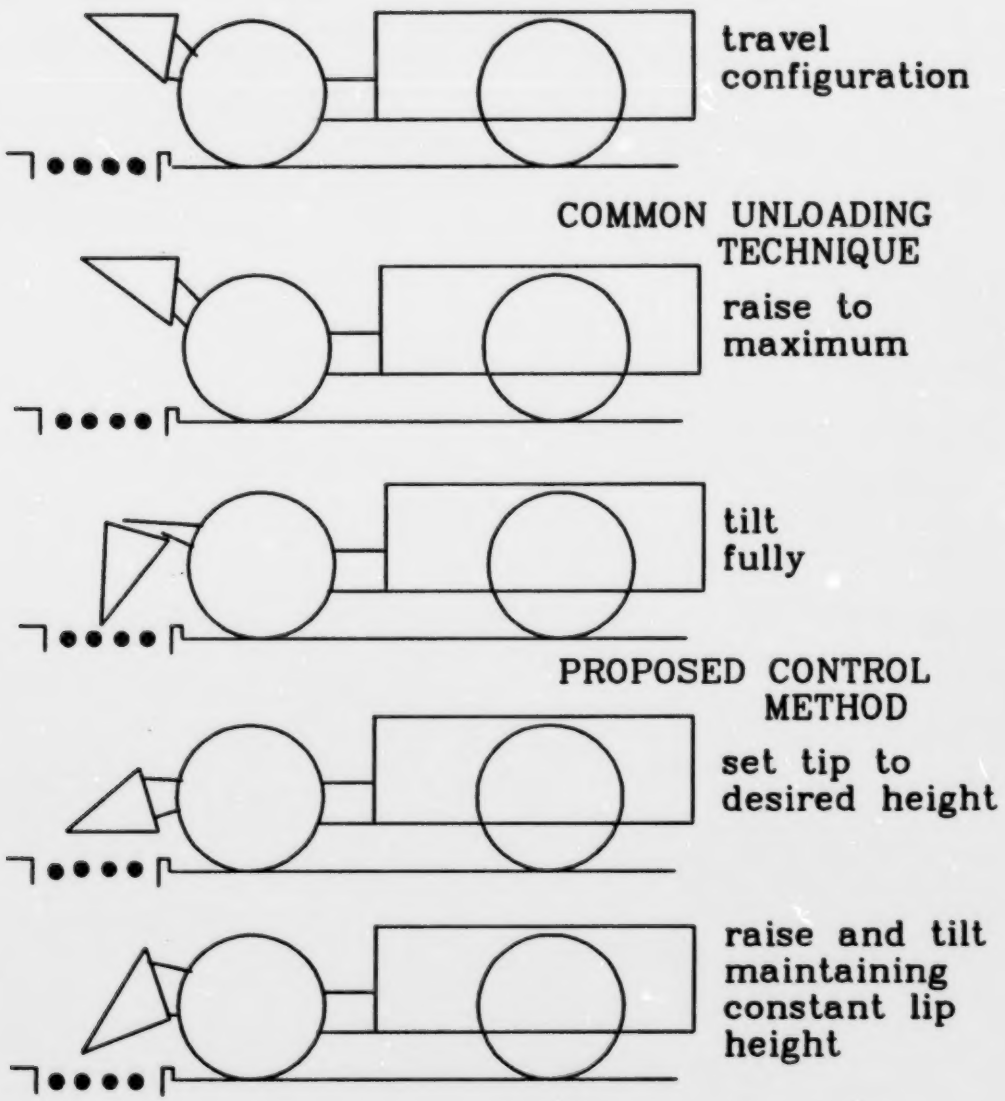

Fig. 2— Improved unloading technique for scooptrams to reduce dust